

10-16-00

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UTILITY PATENT APPLICATION TRANSMITTAL <small>(only for new non-provisional applications under 37 CFR 1.53(b))</small>	Attorney Docket No. Naguib 2000-0238
	First Named Inventor or Application Identifier Ayman F Naguib
	Title Equalization of Transmit Diversity Space-Time Coded Signals
	Express Mail Label no. EK508640604US

To: **Assistant Commissioner for Patents
Box Patent Application
Washington D.C. 20231**

APPLICATION ELEMENTS	ACCOMPANYING APPLICATION PARTS
<input checked="" type="checkbox"/> Fee Transmittal Form (original and duplicate) <input checked="" type="checkbox"/> Specification Total Pages 10 title cross reference to related applications (e.g. provisional application) background summary brief description of the drawings (if filed) detailed description claims abstract <input checked="" type="checkbox"/> Drawing(s) Total Pages 2 <input checked="" type="checkbox"/> Declaration Total Pages 4 a. <input type="checkbox"/> Newly executed b. <input type="checkbox"/> Copy from a prior application (37 CFR 1.63(d)) (for continuations/divisionals with section below filled out) <input type="checkbox"/> Deletion of Inventor(s) Signed Statement attached deleting inventor(s) named in the prior application. 37 CFR 163 (d)(2) and 1.33(b). <input type="checkbox"/> Incorporation by reference (usable if Declaration is a copy): The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied, is considered as being part of the disclosure of the accompanying application is hereby incorporated by reference herein. <input type="checkbox"/> Other	<input checked="" type="checkbox"/> Assignment <input checked="" type="checkbox"/> Recordation form <input checked="" type="checkbox"/> Power of Attorney <input checked="" type="checkbox"/> Postcard <input type="checkbox"/> Small entity statement <input type="checkbox"/> Certified copy of priority documents <input type="checkbox"/> Information disclosure statement <input type="checkbox"/> Copies of IDS citations <input type="checkbox"/> 37 CFR 3.73(b) Statement <input checked="" type="checkbox"/> check <input type="checkbox"/> Other

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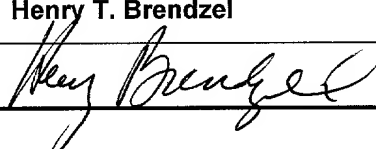
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FEE TRANSMITTAL <i>Patent Fees are subject to annual revisions on October 1. These are the fees effective November 10, 1998 Small entity payments must be supported by a small entity statement. Otherwise, large entity fees must be paid. See Forms PTO/SB/09-12.</i>		<i>Complete if Known</i>	
		Application Number	60/196599
		Filing Date	4/13/00
		First Named Inventor	Ayman F Naguib
		Examiner Name	
		Group/Art Unit	
TOTAL AMOUNT OF PAYMENT	(\$) 750	Attorney Docket ID	Naguib 2000-0238

METHOD OF PAYMENT (check one)		FEE CALCULATION (continued)																																																															
1. The Commissioner is hereby authorized to charge indicated fees and other underpayments, and credit overpayments to: Deposit Account Number Deposit Account Name 500732 Henry T. Brendzel <input checked="" type="checkbox"/> Charge any additional Fee Required under 37 CFR 1.16 and 1.17 <input type="checkbox"/> Charge the Issue Fee Set in 37 CFR 1.18 at the Mailing of the Notice of Allowance 2. <input type="checkbox"/> Payment enclosed: <input type="checkbox"/> Check <input type="checkbox"/> Money Order <input type="checkbox"/> Other		3. ADDITIONAL FEES <table border="1"> <thead> <tr> <th>Fee Description</th> <th>Fee Paid</th> </tr> </thead> <tbody> <tr><td>Surcharge - late filing fee or oath</td><td></td></tr> <tr><td>Surcharge - late provisional filing fee or cover sheet</td><td></td></tr> <tr><td>Non-English specification</td><td></td></tr> <tr><td>For filing request for reexamination</td><td></td></tr> <tr><td>Requesting publication of SIR prior to Examiner action</td><td></td></tr> <tr><td>Requesting publication of SIR after Examiner action</td><td></td></tr> <tr><td>Extension for reply within the first month</td><td></td></tr> <tr><td>Extension for reply within the second month</td><td></td></tr> <tr><td>Extension for reply within the third month</td><td></td></tr> <tr><td>Extension for reply within the fourth month</td><td></td></tr> <tr><td>Extension for reply within the fifth month</td><td></td></tr> <tr><td>Notice of Appeal</td><td></td></tr> <tr><td>Filing a brief in support of an appeal</td><td></td></tr> <tr><td>Requesting an oral hearing</td><td></td></tr> <tr><td>Petition to institute a public use proceeding</td><td></td></tr> <tr><td>Petition to revive - unavoidable</td><td></td></tr> <tr><td>Petition to revive - unintentional</td><td></td></tr> <tr><td>Utility issue fee (or reissue)</td><td></td></tr> <tr><td>Design issue fee</td><td></td></tr> <tr><td>Plant issue fee</td><td></td></tr> <tr><td>Petitions to the Commissioner</td><td></td></tr> <tr><td>Petitions related to provisional applications</td><td></td></tr> <tr><td>Submission of Information Disclosure Statement</td><td></td></tr> <tr><td>Recording each patent assignment per property (times number of properties)</td><td>40</td></tr> <tr><td>Filing a submission after final rejection (37 CFR 1.129(a))</td><td></td></tr> <tr><td>For each additional invention to be examined (37 CFR 1.129(b))</td><td></td></tr> <tr><td>Other fee</td><td></td></tr> <tr><td>Other fee</td><td></td></tr> <tr><td>Other fee</td><td></td></tr> <tr><td>SUBTOTAL (2) (\$)</td><td>40</td></tr> </tbody> </table>		Fee Description	Fee Paid	Surcharge - late filing fee or oath		Surcharge - late provisional filing fee or cover sheet		Non-English specification		For filing request for reexamination		Requesting publication of SIR prior to Examiner action		Requesting publication of SIR after Examiner action		Extension for reply within the first month		Extension for reply within the second month		Extension for reply within the third month		Extension for reply within the fourth month		Extension for reply within the fifth month		Notice of Appeal		Filing a brief in support of an appeal		Requesting an oral hearing		Petition to institute a public use proceeding		Petition to revive - unavoidable		Petition to revive - unintentional		Utility issue fee (or reissue)		Design issue fee		Plant issue fee		Petitions to the Commissioner		Petitions related to provisional applications		Submission of Information Disclosure Statement		Recording each patent assignment per property (times number of properties)	40	Filing a submission after final rejection (37 CFR 1.129(a))		For each additional invention to be examined (37 CFR 1.129(b))		Other fee		Other fee		Other fee		SUBTOTAL (2) (\$)	40
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Typed of Printed Name	Henry T. Brendzel			Reg. Number	26,844
Signature				Date	10/13/00
				Deposit Account User ID	

Equalization of Transmit Diversity Space-Time Coded Signals

Related Application

This invention claims priority from Provisional application No. 60/196,599, filed
5 April 13, 2000.

Background

This invention relates to multi-antenna receivers.

Future wireless communications systems promise to offer a variety of multimedia
10 services. To fulfill this promise, high data rates need to be reliably transmitted over
wireless channels. The main impairments of wireless communication channels are time
varying fading due to multipath propagation, and time dispersion. The multipath fading
problem can be solved through antenna diversity, which reduces the effects of multipath
fading by combining signals from spatially separated antennas. The time dispersion
15 problem can be solved by equalization, such as linear, decision feedback, and maximum
likelihood sequence estimation (MLSE).

It has been a standard practice to use multiple antennas at the receiver with some
sort of combining of the received signals, e.g., maximal ratio combining. However, it is
hard to efficiently use receive antenna diversity at remote units, e.g., cellular phones,
20 since they typically need to be relatively simple, small, and inexpensive. Therefore,
receive antenna diversity and array signal processing with multiple antennas have been
almost exclusively used (or proposed) for use at the base station, resulting in an
asymmetric improvement of the reception quality only in the uplink.

Recently, there have been a number of proposals that use multiple antennas at the
25 transmitter with the appropriate signal processing to jointly combat the above wireless
channel impairments and provide antenna diversity for the downlink while placing most
of the diversity burden on the base station. Substantial benefits can be achieved by using
channel codes that are specifically designed to take into account multiple transmit
antennas. The first bandwidth efficient transmit diversity scheme was proposed by
30 Wittneben and it included the transmit diversity scheme of as a special case. See N.
Seshadri and J. H. Winters, "Two Schemes for Improving the Performance of Frequency-
Division Duplex (FDD) Transmission Systems Using Transmitter Antenna Diversity,"

International Journal of Wireless Information Networks, vol. 1, pp. 49-60, Jan. 1994. In V. tarokh, N. Seshadri, and A. R. Calderbank, "Space-Time Codes for High Data Rate Wireless Communications: Performance Criterion and Code Construction," *IEEE Trans. Inform. Theory*, pp. 744-765, March 1998, space-time trellis codes were introduced,

5 where a general theory for design of combined trellis coding and modulation for transmit diversity is proposed. An input symbol to the space-time encoder is mapped into N modulation symbols, and the N symbols are transmitted *simultaneously* from N transmit antennas, respectively. These codes were shown to achieve the maximal possible diversity benefit for a given number of transmit antennas, modulation constellation size, and transmission rate. Another approach for space-time coding, space-time block codes, 10 was introduced by S. Alamouti, in "Space Block Coding: A Simple Transmitter Diversity Technique for Wireless Communications," *IEEE Journal on Selec. Areas. Commun.*, vol. 16, pp. 1451-1458, October 1998 and later generalized by V. Tarokh, H. Jafarkhani, and R. A. Calderbank, in "Space Time block Codes From Orthogonal Designs," *IEEE Trans. Inform. Theory*, vol. 45, pp. 1456-1467, July 1999. 15

Space-time codes have been recently adopted in third generation cellular standard (e.g. CDMA-2000 and W-CDMA). The performance analysis of the space-time codes in the above-mentioned articles was done assuming a flat fading channel. Analysis shows that the design criteria of space-time trellis codes is still optimum when used over a 20 frequency selective channel, assuming that the receiver performs the optimum *matched filtering* for that channel. In addition, although the space-time coding modem described in A. F. Naguib, V. Tarokh, N. Seshadri and A. R. Calderbank, "A Space-Time Coding Based Modem for High Data Rate Wireless Communications," *IEEE Journal on Selec. Areas Commun.*, vol. 16, pp. 1459-1478, October 1998 was designed assuming a flat 25 fading channel, it performed remarkably well when used over channels with delay spreads that are relatively small as compared to the symbol period T_s . However, when the delay spread is large relative to the symbol period, e.g., $\geq T_s / 4$, there was a severe performance degradation.

Summary

In connection with transmitted space-time, trellis encoded, signals that pass through a transmission channel that is characterized by memory, improved performance is realized with a receiver that combines a decoder with an equalizer that selects the trellis transition, s , that minimizes the metric

$$\xi_j(k) = \left| r(k) - \sum_{l=L_1+1}^{L_1} \tilde{h}_j(l) \tilde{s}(k-l) - \sum_{l=L_1+1}^{L+1} \tilde{h}_j(l) \hat{s}(k-l) \right|^2$$

where $\tilde{h}_j(l)$ is related to both the transmission channel and to the encoding structure in the transmitter, $\tilde{s}(k)$ are the (trial) symbols according to a certain transition and $\hat{s}(k)$ are the symbols that were previously decided.

Brief Description of the Drawings

FIG. 1 depicts a transmitter having a plurality of antennas, and a receiving having a plurality of antennas, where the transmission channel between them includes memory;

FIG. 2 illustrates a particular trellis structure for the trellis encoder shown in the FIG. 1 transmitter; and

FIG. 3 is an advantageous constellation mapping.

Detailed Description

FIG. 1 presents the general scenario of a transmitter 10 having N transmit antennas, for example 11-1, and 11-2, and a receiver 20 with 21-1, 21-2, ... 21-M receive antennas, in a frequency selective Rayleigh fading environment. The M receive antennas are coupled to equalizer/decoder 23, equalizer/decoder 23 is coupled to symbol-to-bits mapper 25, and mapper 25 is connected to an outer-code decoder 27 (if the signal transmitted by transmitter 10 is encoded with an outer-code encoder – as shown in transmitter 10). The design and operation of equalizer/decoder, which may be implemented with a conventional digital signal processor, is the subject of this disclosure,

Generally, the impulse response of the transmission channel between the i -th transmitting to the j -th receiving antennas, when modeled with a time varying FIR impulse response, is

$$g_y(k) = \sum_{l=0}^L h_y(k, l) \delta(k-l), \quad (1)$$

which includes the effects of the transmitter and receiver pulse shaping filters and the physical multipath channel. Equation (1) incorporates the notion that for various reasons, such as a plurality of different-distance paths, the transmission channel includes memory. Without loss of generality, it is assumed that the channel model order (i.e., the channel's memory) is $L+1$. It is also assumed that the channel parameters $\{h_y(k, l), i = 1 \dots M\}$ are invariant within a data burst, although they may be varying from burst to burst. In cellular systems such as GSM, the length of a data burst is about of 0.58 ms, and compared to the coherence time of the channel at 60 MPH mobile velocity, which is approximately 12.5 ms, the burst length is small enough such that the block time-invariant channel model is valid. This assumption is satisfied in most of the GSM environment.

The $h_y(k, l)$ elements are modeled as iid complex Gaussian random variables with zero mean and variance $\sigma_h^2(l)$, and the channel is assumed to be passive; that is

$$\sum_{l=0}^L \sigma_h^2(l) = 1. \quad (2)$$

When $s(k)$ is the signal that is applied to time-space encoder 19 of FIG. 1, the corresponding output is $\{c_1(k), c_2(k), \dots, c_N(k)\}$, where $c_i(k)$ is the code symbol transmitted from antenna i at time k . The received signal at receive antenna j can be expressed by:

$$r_j(k) = \sum_{i=1}^N \sum_{l=0}^L h_{ij}(l) c_i(k-l) + n_j(k), \quad 1 \leq j \leq M, \quad (3)$$

where $n_j(k)$ is a sequence of iid complex Gaussian noise samples with zero mean and variance σ_n^2 . One of the summations in equation (3) can be put in a matrix form, to yield

$$r_j(k) = \sum_{i=1}^N \mathbf{g}_{ij} \cdot \mathbf{c}_i(k) + n_j(k), \quad (4)$$

where $\mathbf{g}_{ij} = [h_{ij}(0) h_{ij}(1) \dots h_{ij}(L)]$ and $\mathbf{c}_i(k) = [c_i(k) c_i(k-1) \dots c_i(k-L)]^T$. The output of

the M receive antennas at time k can thus be expressed by

$$\begin{aligned}\mathbf{r}(k) &= [r_1(k)r_2(k)\cdots r_M(k)]^T \\ &= \sum_{l=1}^N \mathbf{H}_l \cdot \mathbf{c}_l(k) + \mathbf{n}(k)\end{aligned}\quad (5)$$

where

$$\begin{aligned}\mathbf{n}(k) &= [n_1(k)n_2(k)\cdots n_M(k)]^T \\ \mathbf{H}_l &= \begin{bmatrix} \mathbf{g}_{l1} \\ \mathbf{g}_{l2} \\ \vdots \\ \mathbf{g}_{lM} \end{bmatrix} = [\mathbf{h}_l(0)\mathbf{h}_l(1)\cdots\mathbf{h}_l(L)], \text{ and} \\ \mathbf{h}_l(l) &= [h_{l1}(l)h_{l2}(l)\cdots h_{lM}(l)]^T.\end{aligned}$$

The noise vector $\mathbf{n}(k)$ has a zero mean and covariance $\mathbf{R}_n = \sigma_n^2 \cdot \mathbf{I}_{M \times M}$.

Extending equation (5) to a $D+1$ sequence of received signals (e.g., a D -stage shift register, yielding $D+1$ taps), a vector $\mathbf{x}(k)$ can be considered that can be expressed by

$$\mathbf{x}(k) = [\mathbf{r}(k)^T \mathbf{r}(k-1)^T \cdots \mathbf{r}(k-D)^T]^T.$$

The new space-time data model is then given by

$$\mathbf{x}(k) = \sum_{l=1}^N \mathfrak{H}_l \cdot \bar{\mathbf{c}}_l(k) + \bar{\mathbf{n}}(k) \quad (6)$$

where $\bar{\mathbf{c}}_l(k) = [c_l(k), c_l(k-1), \dots, c_l(k-L-D)]^T$, $\bar{\mathbf{n}}(k) = [\mathbf{n}(k)^T \mathbf{n}(k-1)^T \cdots \mathbf{n}(k-L)^T]^T$, and

$$\mathfrak{H}_l = \begin{bmatrix} \boxed{\mathbf{H}_l} & \cdots & \mathbf{0} \\ & \ddots & \\ \mathbf{0} & \cdots & \boxed{\mathbf{H}_l} \end{bmatrix} \quad (7)$$

is an $M(D+1) \times (L+D+1)$ matrix. The noise vector $\bar{\mathbf{n}}(k)$ has a zero mean and covariance $\mathbf{R}_{\bar{n}} = \sigma_n^2 \cdot \mathbf{I}_{M(D+1) \times M(D+1)}$.

With the above analysis in mind, one might consider the situation where the mapper 14 is an 8-PSK 8-state mapper, followed by a trellis encoder 16 whose output is applied to space-time coder 19. The input to coder 19 forms a first output of the space-time coder, and is applied to antenna 11-1. This input is also applied to delay element 17 and thence to multiplier 18, which creates a second output of the space-time coder. That second output is applied to antenna 11-2. Multiplier 18 multiplies the mapped signal by

−1 (rotates it by 180) when the symbol applied to multiplier 18 is odd. Advantageously, the mapping within element 14 is as depicted in FIG. 3; that is, traversing the unit circle counterclockwise starting with 0, the sequence of mappings is {0,7,6,1,5,2,3,4}.

The trellis of encoder 16 is shown in FIG. 2. For this arrangement, the input bit stream is grouped into group of three bits each and each group is mapped into one of the 8 constellation points, which are also states of the trellis encoder. The column to the left of the trellis is the state label and each row to the right of the trellis represents the edge labels for transitions from the corresponding state. An edge label c_1c_2 indicates that symbol c_1 is transmitted from the first antenna and symbol c_2 is transmitted from second antenna. To illustrate, assuming that the encoder starts from state ‘0’ – which is the conventional assumption-- if the input sequence is {0 1 5 7 6 4} then operating pursuant to the FIG. 2 trellis yields the sequence {0 1 5 7 6 4} that is transmitted over the first antenna and the sequence {0 0 5 1 3 6} that is transmitted over the second antenna.

For data rates on the order of the coherence bandwidth of the channel, or larger, an equalizer needs to be used to compensate for the intersymbol interference induced by the *resolvable* multipath receptions. There are two basic, yet powerful, equalization techniques that are used for equalization over wireless channels: the probabilistic symbol-by-symbol MAP algorithm, which provides the MAP-probabilities for each individual symbol, and the Viterbi algorithm (VA), which is a maximum likelihood sequence estimator (MLSE) that outputs the ML-channel path. Both techniques have the advantage that they gather energy from all channel tap gains (therefore taking full advantage of the diversity gain offered by the multipath propagation) without suffering from noise enhancement or error propagation. This is rather an important feature because in wireless propagation environments the reflections may be stronger than the direct path. The main problem of both approaches, however, is their complexity in terms of the equalizer states. For example, in case of space-time coding with N transmit antennas and a channel response with length $L + 1$, the number of equalizer states will be $(\mathcal{M}^N)^L$, where \mathcal{M} is the number of constellation points. That is, the equalizer complexity is exponential in terms of number of transmit antennas and channel memory.

The equalizer complexity problem can be solved by using a reduced complexity approach by M. V. Eyuboglu and S. U. Qureshi, in “Reduced-State Sequence Estimation

with Set Partitioning and Decision Feedback,” *IEEE Trans. Commun.*, vol. COM-36, pp. 12-20, January 1988. However, reduced complexity techniques suffer from performance degradation if the channel response is not minimum phase, or nearly so. Since wireless channels are time varying and hence the minimum phase condition is not guaranteed all the time, a whitened matched filter or a pre-cursor equalizer must be used to render the channel minimum phase all the time. Although designing a whitened matched filter is well known for the classical equalization problem, it is not known for space-time coding with transmit diversity. This is because, as mentioned earlier, the received signal at the receiver is the superposition of all transmitted signals that propagated through totally independent channels. Consequently, the job of the whitened matched filter in this case is to render *all* of these channels minimum phase at the same time; and it is not known how to achieve this.

To overcome this problem, the following discloses a reduced complexity approach that uses the structure that is present in some space-time trellis codes, such as the one presented in FIG. 2.

Defining $\mathbf{s}(k) \equiv [s(k) \ s(k-1) \ \cdots \ s(k-L)]^T$, from FIG. 2 it can be seen that the code symbols to be transmitted from the first antenna (at time $k, k-1, \dots, k-L$) are $\mathbf{c}_1(k) = [s(k) \ s(k-1) \ \cdots \ s(k-L)]^T$ and, hence, $\mathbf{c}_1(k) = \mathbf{s}(k)$. The corresponding code symbols to be transmitted from the second antenna can be expressed by

$$\mathbf{c}_2(k) = \mathbf{S} \cdot \mathbf{s}(k-1)$$

where $\mathbf{S} = \text{diag}\{f(l)\}_{l=1 \dots L+1}$ and

$$f(l) = 1 - 2 * \text{mod}\left(\frac{\angle s(k-1)}{\pi/4}, 2\right) \quad (8)$$

Hence, the received signal vector at the M receive antennas in (5) can be rewritten as

$$\begin{aligned} \mathbf{r}(k) &= \mathbf{H}_1 \cdot \mathbf{s}(k) + \mathbf{H}_2 \cdot \mathbf{S} \cdot \mathbf{s}(k-1) + \mathbf{n}(k) \\ &= ([\mathbf{H}_1 : \mathbf{0}] + [\mathbf{0} : \mathbf{S} \cdot \mathbf{H}_2]) \begin{bmatrix} s(k) \\ \vdots \\ s(k-1) \end{bmatrix} + \mathbf{n}(k) \end{aligned} \quad (9)$$

For the j -th receive antenna, this reduces to

$$r_j(k) = \sum_{l=0}^{L+1} \tilde{h}_j(l) s(k-l) + n(k) \quad (10)$$

where

$$\tilde{h}_j(l) = \begin{cases} h_{1j}(0) & l = 0 \\ h_{1j}(l) + f(l) \cdot h_{2j}(l-1) & l = 1 \cdots L \\ f(L+1) \cdot h_{2j}(L) & l = L+1 \end{cases} \quad (11)$$

Note that the delay diversity case for 8-PSK with 2 transmit antenna can be obtained by setting $f(l) = 1 \forall l$ in equations (9), (10), and (11). Using equation (10), a branch metric for the j -th receive antenna at time k in a reduced-complexity MLSE is

$$\xi_j(k) = \left| r(k) - \sum_{l=L_1+1}^{L_1} \tilde{h}_j(l) \tilde{s}(k-l) - \sum_{l=L_1+1}^{L+1} \tilde{h}_j(l) \hat{s}(k-l) \right|^2 \quad (12)$$

where $\tilde{s}(k)$ are the (trial) symbols according to a certain transition and $\hat{s}(k)$ are the previous symbols along the path history. Under some circumstances, a modification of the equation (12) metric may be employed, which provides a delayed decision. The modified metric can be expressed by

$$\xi_j(k) = \left| r(k-1) - \sum_{l=0}^{L_1} \tilde{h}_j(l) \tilde{s}(k-l) - \sum_{l=L_1+1}^{L+1} \tilde{h}_j(l) \hat{s}(k-l) \right|^2 \quad (13)$$

The total path metric for the M receive antennas will be

$$\xi(k) = \sum_{j=1}^M \xi_j(k). \quad (14)$$

In short, equalizer/MSE decoder 23 within receiver 20 needs to obtains an estimate of the transmission channel parameters in a conventional way, e.g., through use of training sequences sent by the transmitter, and proceed to decode received symbols by selecting as the transmitted signal that signal which minimizes the equation (12) metric.

Claims:

1. A receiver that combines a decoder with an equalizer that selects a trellis transition, s , that minimizes the metric

$$\xi_j(k) = \left| r(k) - \sum_{l=L_1+1}^{L_1} \tilde{h}_j(l) \tilde{s}(k-l) - \sum_{l=L_1+1}^{L+1} \tilde{h}_j(l) \hat{s}(k-l) \right|^2$$

- 5 where $r(k)$ is a signal received by said receiver at time k , $\tilde{h}_j(l)$ is related to both the transmission channel and to the encoding structure in the transmitter, $\tilde{s}(k)$ is a trial symbols specified by a selected trellis transition and $\hat{s}(k)$ is a symbols that was previously decided.

Abstract

In connection with transmitted space-time, trellis encoded, signals that pass through a transmission channel that is characterized by memory, improved performance is realized with a receiver that combines a decoder with an equalizer that selects the trellis transition, s , that minimizes the metric

$$\xi_j(k) = \left| r(k) - \sum_{l=L_1+1}^{L_1} \tilde{h}_j(l) \tilde{s}(k-l) - \sum_{l=L_1+1}^{L+1} \tilde{h}_j(l) \hat{s}(k-l) \right|^2$$

where $\tilde{h}_j(l)$ is related to both the transmission channel and to the encoding structure in the transmitter, $\tilde{s}(k)$ are the (trial) symbols according to a certain transition and $\hat{s}(k)$ are the symbols that were previously decided.

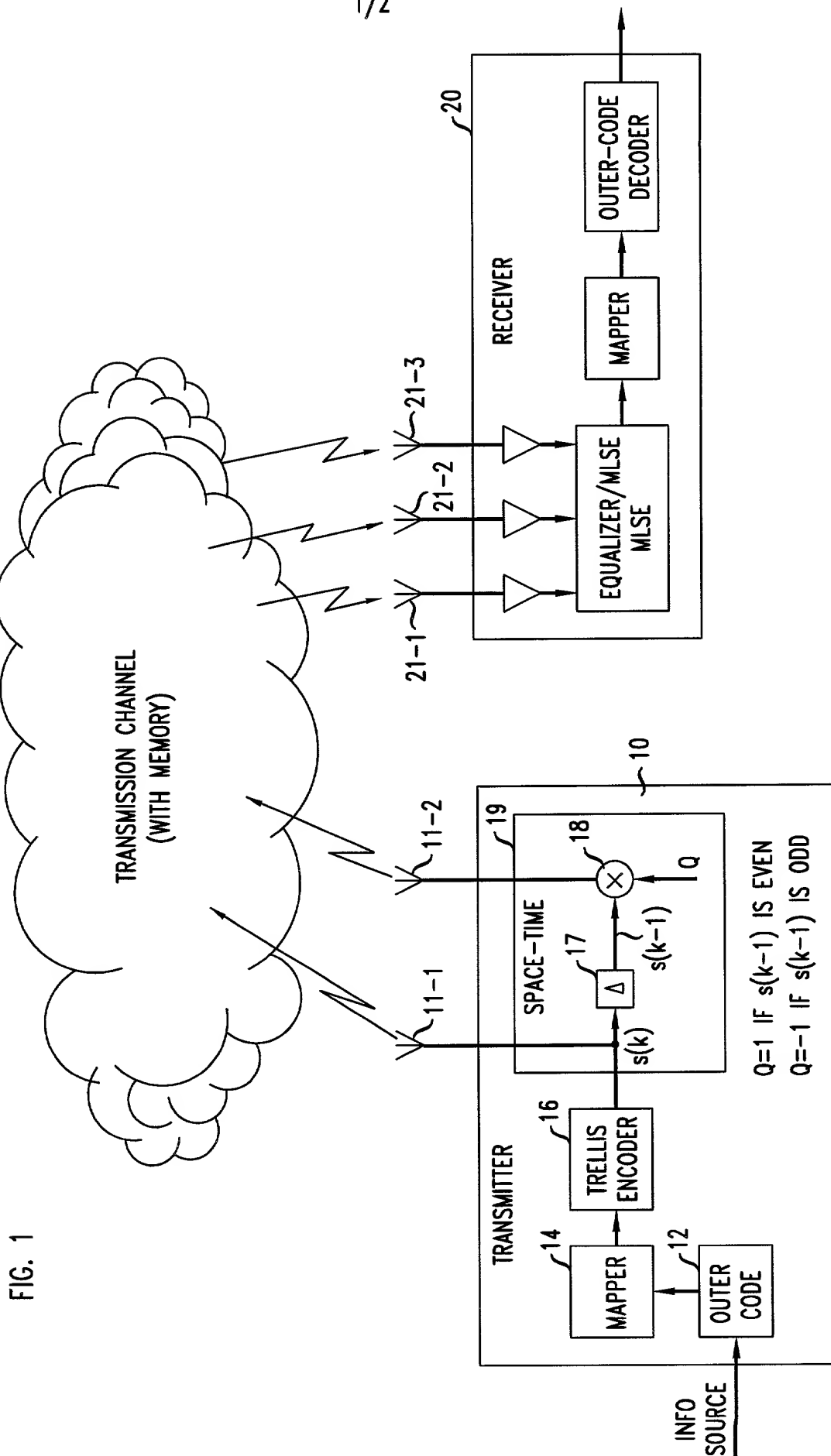


FIG. 2

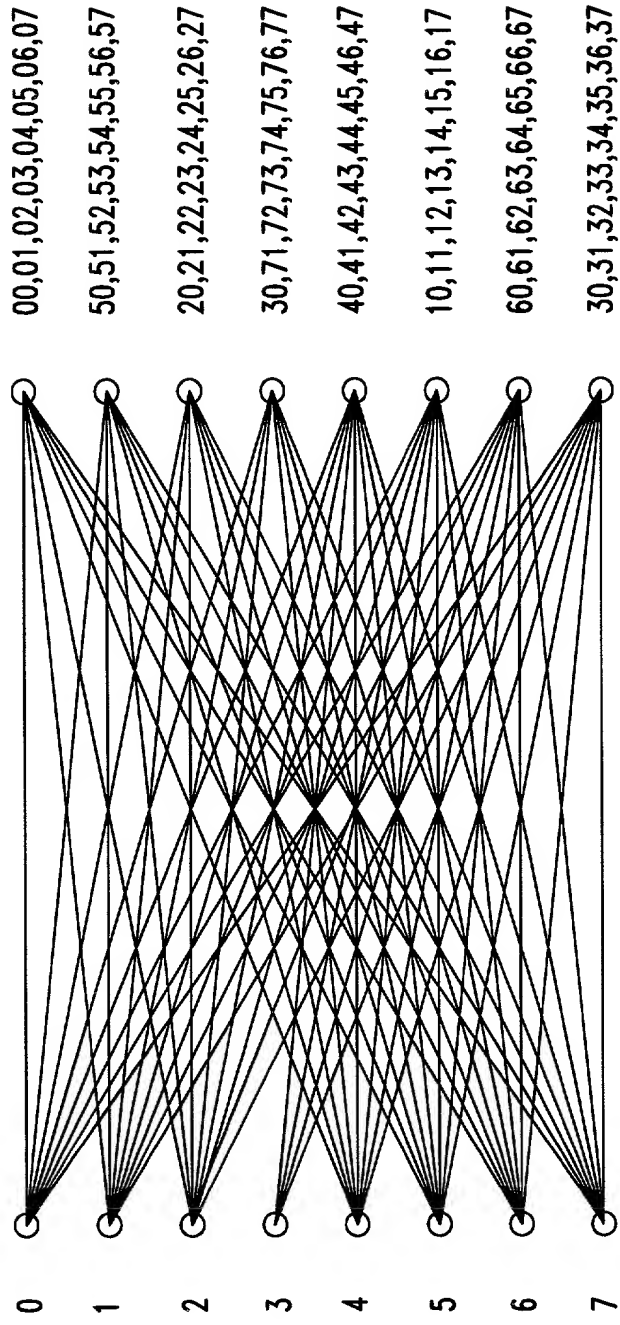
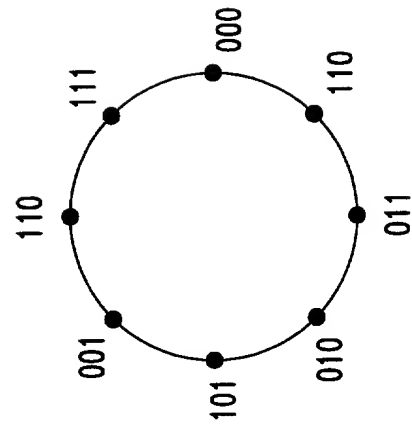


FIG. 3



IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

Declaration and Power of Attorney

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **Equalization of Transmit Diversity Space-Time Coded Signals** the specification of which was filed on 4/13/00, as provisional application Serial No. 60/196599.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me, which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventors' certificate listed below and have also identified below any foreign application for patent or inventors' certificate having a filing date before that of the application on which priority is claimed:

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, we acknowledge the duty to disclose all information known to us to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Provisional Application 60/196,599, filed April 13, 2000

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorney(s) with full power of substitution and revocation, to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

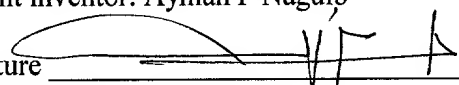
Samuel H. Dworetsky	(Reg. No. 27873)	Thomas A. Restaino	(Reg. No. 33444)
Michele L. Conover	(Reg. No. 34962)	Cedric G. DeLaCruz	(Reg. No. 36498)
Rohini K. Garg	(Reg. No. 45272)	Thomas M. Isaacson	(Reg. No. 44166)
Benjamin S. Lee	(Reg. No. 42787)	Robert B. Levy	(Reg. No. 28234)
Susan E. McGahan	(Reg. No. 35948)	Gary H. Monka	(Reg. No. 35290)
Jeffrey M. Navon	(Reg. No. 32711)	Stephen K. Pentlicki	(Reg. No. 40125)
Alfred G. Steinmetz	(Reg. No. 22971)		

I also appoint the following as associate attorney(s), with full power to prosecute said application, to make alternations and amendments therein, and to transact all business in the Patent and Trademark Office connected therewith:

Henry T. Brendzel (Reg. No. 26,844)
William Ryan (Reg. No. 26,844)

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IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

Declaration and Power of Attorney

As a below named inventor, I hereby declare that:

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I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **Equalization of Transmit Diversity Space-Time Coded Signals** the specification of which was filed on 4/13/00, as provisional application Serial No. 60/196599.

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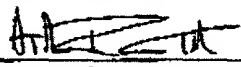
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